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# THESIS

**REENGINEERING OF THE F/A-18 AIRCRAFT'S INTERMEDIATE LEVEL HYDRAULIC MAINTENANCE**

by

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June 1996

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# REENGINEERING OF THE F/A-18 AIRCRAFT'S INTERMEDIATE LEVEL HYDRAULIC MAINTENANCE

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# ABSTRACT

The continued down-sizing of the Department of Defense (DoD) into the 21st century and the resulting budget constrained realities will force the Navy to adopt innovative measures to save costs, while not sacrificing readiness. The Navy's immediate future in aviation lies in the readiness of the F/A-18 Hornet aircraft weapons system. Present experience shows the F/A-18's hydraulic system is not performing effectively and subsequently is one of the top readiness degraders. In this thesis, we analyze reengineering and consolidating duplicate intermediate level F/A-18 hydraulic system maintenance capabilities. Consolidating the maintenance of duplicate capabilities into one facility per coast, as we propose for the intermediate maintenance facilities for these hydraulic components, would reduce cost while maintaining readiness. We develop a comparative spreadsheet model to analyze a Prime Intermediate Maintenance Activity (PIMA) operating as a consolidated facility to investigate the effects of consolidating production and its impact on readiness. Based on our analysis, we conclude that the proposed consolidation is a viable option.

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# I. INTRODUCTION

## A. BACKGROUND

Reliable weapons systems are critical to the success of the Department of Defense (DoD) in meeting its missions. Reduced budgets have produced binding budget constraints that have challenged logisticians in all communities. Each of the Navy's communities must face these obstacles with innovative and forward-looking change to meet the demands of the 21st century. In concert with the responsibility to make fiscally responsible change, the requirement to simultaneously maintain the readiness of weapons systems is paramount. More specifically, the Naval aviation community's success lies foremost in future policy innovations and the readiness of the F/A-18 Hornet weapons system.

Present experience shows the F/A-18's hydraulic system is not performing as designed or planned for and subsequently is one of the aircraft's top readiness degraders. Figure 1 amplifies the current readiness status of the F/A-18 by outlining five hydraulic components among the aircraft's top ten readiness degraders. In this thesis, we evaluate the impact of consolidating the repair of these hydraulic components. We will outline how the current Navy and Marine Corps' maintenance policy and physical layout contributes to the hydraulic related shortfalls seen in the F/A-18's readiness.

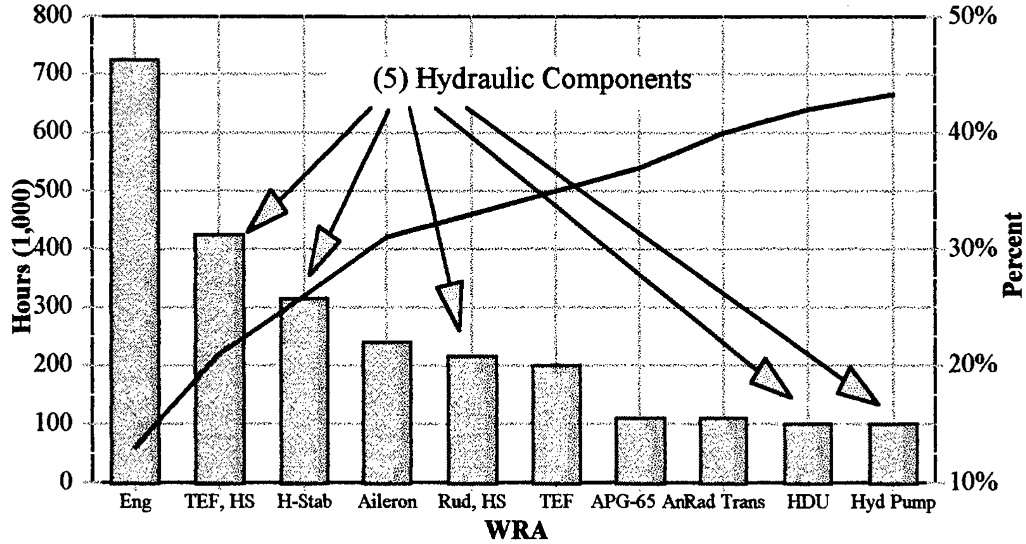


**Figure 1. F/A-18 Top Ten Readiness Degraders (1995 Data)**

The F/A-18 aircraft is supported with three levels of maintenance - depot, intermediate and organizational. We will concentrate on the F/A-18's intermediate maintenance concept which is currently centered around four Prime Intermediate Maintenance Activities (PIMA). The Navy's two prime intermediate maintenance facilities, known as Aircraft Intermediate Maintenance Departments (AIMD), are located in Lemoore, California and Jacksonville, Florida. The Marine Corps' two prime intermediate maintenance facilities, a component of the Marine Aviation Logistics Squadrons (MALS), are located in San Diego, California and Beaufort, South Carolina.

Maintaining two PIMA's on each coast serves primarily to facilitate a separation of the Marine Corps' and Navy's aircraft and support structures, but overlooks the potential benefits of consolidation. The integration of Marine Corps

and Navy aviation assets or intermediate maintenance support is evident today in limited capacities. For example, a small percentage of Marine Corps F/A-18 aircraft deploy onboard selected Navy aircraft carriers. The deployment of these aircraft coincides with Marine Corps maintenance and support personnel augmenting the aircraft carrier's AIMD. In contrast, the exchange of personnel or aircraft at the PIMA shore sites is much more limited.

Consolidation of PIMA's on each coast can potentially reduce repair Turnaround Time (TAT) at the intermediate and depot levels and increase the number of assets repaired at the PIMA's, thus improving readiness and providing cost savings in Aviation Depot Level Repairable (AVDLR) charges. Additional areas that may be effected by a consolidation initiative are military manpower, spares inventory, and Engineering Technical Support (ETS) to identify some of the fundamental categories. This consolidation of Marine Corps and Navy intermediate maintenance organizations will not come without resistance stemming from strong service cultures, political issues and service identity. Overcoming this stumbling block will require high level leadership's involvement, forward-looking thinking and state of the art management practices - reengineering.

Reengineering is defined as dramatic and radical changes to existing practices to instill change to antiquated, ineffective ways of conducting business. Reengineering cannot be carried out in small and cautious incremental steps. This

approach requires management throw out old notions of organization and production operations - (Hammer and Champy, 1993).

Two commercial reengineering examples that demonstrate its potential are the Whirlpool Corporation and Wal Mart examples. Whirlpool's change in attitude on the part of their management and employees was demonstrated when they imparted dramatic changes from their historical modus operandi. In addition to implementing a productivity based gain-sharing incentive, a revised management policy allowed management and employees to utilize flexible and discretionary work rules. Their training program changed from a training program that focused on compliance, to a program that emphasized training employees and management to use their heads as well as their hands. This complete shift in policy enabled them to lower prices in the face of a consumer price index that had risen 20% in the previous four years. The second example occurred when Wal Mart granted Proctor & Gamble complete autonomy to make *their* forecasting and inventory decisions encompassing all diaper products sold at Wal Mart. This reengineering change has eliminated costly stockouts, high inventory holding costs and resulted in quick product turnover. Essentially, Wal Mart's inventory is so efficiently managed that it now sells P & G's products before even paying for them. Each of these corporations in the civilian sector successfully faced demands of extreme fiscal challenges by radically changing existing policies - reengineering.

The initiative to reengineer and consolidate the current mode of operation originates from the tremendous potential to reduce cost while maintaining or even improving readiness levels. However, the complexity and risk of reengineering aviation maintenance policy and consolidating facilities has limited the growth and change in these areas. This risk of implementing changes of significant magnitude, as discussed above, can be minimized and measured through the use of comparative spreadsheet analysis.

Spreadsheet analysis can partially assess the merit of consolidating two prime F/A-18 intermediate level repair sites without having to physically move a single asset. To combat the risks of reengineering, analyses like these have proved to be an effective tool for evaluating the impact of various maintenance policies.

Evaluating the impact of consolidating PIMA's and reengineering initiatives will be simplified by selecting a segment of the F/A-18 intermediate maintenance support. The focus of this thesis is evaluating the potential consolidation of two west coast PIMA's hydraulic component repair capabilities for one component. This reduction of scope will facilitate the development of a spreadsheet analysis to accurately portray the desired characteristics of the PIMA. Further, the consolidation of intermediate capabilities may only be practical in certain areas.

The principal PIMA test equipment in this consolidation analysis is the F/A-18 Servocylinder Test Station (STS). The F/A-18 STS is an automated test station. It

is used to identify and troubleshoot causes of failures on F/A-18 hydraulic components. The principal hydraulic component in this model is the Trailing Edge Flap Hydraulic Servovalve (TEF/ HS). The F/A-18 has two TEF/HS's. The TEF/HS is an electro-hydraulic flight control servoactuator that mechanically positions the aircraft's trailing edge flaps.

We will study the feasibility of consolidating the hydraulic repair capabilities at AIMD Lemoore and MALS-11 Miramar, and the resulting effects on aircraft readiness and AVDLR costs by using spreadsheet analysis. The development of Super "I" (intermediate) levels is not new, however this thesis looks at the development of a Super Hydraulic "I" Level. The analysis will be organized into six areas. The six measures of effectiveness are (1) AVDLR and Aviation Operations Maintenance (AOM) costs, (2) transportation, (3) manpower, (4) spares, (5) facilities, and (6) product improvement initiatives.

The F/A-18 has many other components that are good candidates for consolidated PIMA support, however, the investigation of them is beyond the scope of this thesis. As stated, the scope of this thesis is limited to the discussion of consolidating PIMA support for the TEF/HS. The reader may infer a reasonable association with other hydraulic components that are tested with the STS.

## B. THESIS ORGANIZATION

This thesis is organized as follows. Chapter II provides background on the STS and TEF/HS. Chapter III provides an a detailed breakdown of the analyses development and methodology. Chapter IV examines the results of the analyses and Chapter V contains conclusions, recommendations and final remarks.

# II. F/A-18 HYDRAULIC INTERMEDIATE MAINTENANCE

## A. BACKGROUND

The Chief of Naval Operations (CNO) sponsors and directs the Naval Aviation Maintenance Program (NAMP). The principal objective of the NAMP is to "achieve and continually improve aviation material readiness and safety standards . . . with optimum use of manpower, material, and funds." In this thesis we attempt to satisfy these requirements set by the CNO through the consolidation of duplicate intermediate level maintenance capabilities. Wirwille and Ainsworth (1991) outlined the cost savings benefits of consolidating all duplicate capabilities found in major Aircraft Intermediate Maintenance Departments (AIMD) in the same geographic area. Cook (1992) narrowed the scope of their thesis and focused on a single duplicate capability at only one pair of AIMD's in the same geographic area. In this thesis, we focus on a single duplicate capability that exists between a single Navy AIMD and a single Marine Corps Marine Aviation Logistics Squadron (MALS). For the purpose of this thesis, the interpretation of "the same geographic area" means, "located on the same coast of the United States of America."

## B. F/A-18 INTERMEDIATE LEVEL MAINTENANCE

The foundation of the NAMP is based on the fundamental separation of aeronautical maintenance into three levels. This concept divides aeronautical

maintenance into depot, intermediate and organizational levels. The thrust of this framework is to increase operational readiness and availability, reduce costs and enhance preparedness. The three levels can be best be compared with a pyramidal hierarchy. Each successive level, beginning with the organizational level, increases in depth, scope and range of maintenance. The organizational level (squadrons), with the most numerous sites, makes up the base of the pyramid and is the most generalized type of maintenance performed. The depot level (Naval Aviation Depots and/or Original Equipment Manufacturer), with the least number of sites, is at the top of the pyramid and is the most specialized maintenance performed. The intermediate level (AIMD, MALS) falls between these two levels in the pyramid's structure.

The goal of the intermediate maintenance level is to enhance and sustain the mission capability and readiness of user activities by providing high quality and timely support with the lowest practical expenditure of scarce resources. PIMA's are traditionally located at or near the operational user activity site, however, this is not always the case, nor necessary. Maintenance personnel at the intermediate level usually require higher skill levels and utilize a more extensive range of test equipment than their counterparts at the organizational level. The rudimentary tasking of the intermediate level is the repair of end items through the removal and replacement of subcomponents and piece parts.

The F/A-18 aircraft obtains intermediate support primarily from four PIMA's. They are located in Lemoore, California, Jacksonville, Florida, San Diego, California and Beaufort, South Carolina. Each coast is comprised of one Navy and one Marine Corps PIMA. The four PIMA's perform indirect and direct support for F/A-18 user activities at the organizational level.

The principal intermediate level test equipment used in support of F/A-18 hydraulic components is the F/A-18 Servocylinder Test Station (STS). This test station is used for the maintenance of the TEF/HS. The STS and TEF/HS are each discussed in greater detail below.

### 1. Aviation Depot Level Repairables (AVDLR)

AVDLR's are components, commonly referred to as *repairables,* that are repaired at the organizational, intermediate and depot levels. The depth of repair follows the pyramidal hierarchy outlined above. AVDLR's are designated as such based on their complexity, size, cost, quantities and reliability during the level of repair analysis.

Repairables that are processed by the intermediate levels of maintenance, that cannot be repaired at that level of maintenance, are classified as Beyond Capability of Maintenance (BCM). The reasons for classifying a component as BCM include:

- Repair not authorized
- Lack of equipment, tools or facilities

- Lack of technical skills
- Lack of parts
- Failed check and test
- Lack of technical data
- Beyond authorized repair depth
- Administrative
- Condemned

Each repairable is designated a flat depot level maintenance repair rate that represents the depot's repair costs, and is billed to the intermediate level for each BCM action. The intermediate level facility is required to manage BCM's utilizing an annual budget for AVDLR costs.

The intermediate maintenance facility purchases subcomponents and consumables to effect repairs to repairables at the intermediate level. These charges are applied to the Aviation Operations Maintenance (AOM) account. Although the AVDLR and AOM accounts are tracked and maintained separately, this is done for accounting purposes only. The dollars for each of these accounts are taken from the Operations and Maintenance (O&M) appropriation.

## 2. Background and Description of Equipment

### a. *Servocylinder Test Station (STS)*

The F/A-18 Servocylinder Test Station (STS) is an automated test station that helps operators make repairs to F/A-18 hydraulic components. Historical

| Location | STS Benches |
|---|---|
| NAS Lemoore | 2 |
| NAS Cecil | 2 |
| MCAS Beaufort[1] | 2 (vans) |
| MCAS Miramar[1] | 2 (vans) |
| NAS Dallas[1] | 1 (vans) |
| NAS New Orleans | 1 |
| NAS Patuxent River | 1 |
| NADEP Jacksonville | 3 |
| NADEP North Island | 3 |
| HR Textron, Los Angeles[2] | 3 (2 - FA18E/F) |
| Iwakuni | 2 |
| Pt. Mugu | 1 |
| All CV/CVN's[3] | 1 per CV/CVN |

**Figure 2. Servocylinder Test Station (STS) Locations**

**Note 1**: STS assets located in vans are deployable assets. There are two vans per STS. All others are hard-sited.
**Note 2**: HR Textron has three STS benches (government furnished equipment (GFE)). Two benches are being used to develop F/A18E/F test capability.
**Note 3**: All CV/CVN's deploy with one STS asset.

data supports that the STS is not effectively troubleshooting problems. The Beyond Capability of Maintenance (BCM) rates for hydraulic components tested on the STS is considerably higher than originally projected. The cause of this unplanned increase in BCM's can also be attributed to some design shortfalls in the components themselves. This is outlined in detail for the TEF/HS in the ensuing section. The result of the unplanned increased BCM rates is a proportional unplanned increase in AVDLR charges to the intermediate activity. Within a small geographical area on the west coast, the Navy and the Marine Corps maintain three F/A-18 intermediate level repair sites with Servocylinder Test Stations (STS) for testing hydraulic components. In addition to the STS assets located in San Diego, California and Lemoore, California, a third STS site is in Fallon, Nevada. The STS bench is also located at other "non-prime" IMA sites that provide hydraulic component repair on a smaller scale as outlined in Figure 2.

The STS will continue to serve the current F/A-18 program and in addition will be the prime test equipment for the follow-on F/A-18 E/F aircraft. The F/A-18 E/F is the 21st century F/A-18 variant and has just begun the Low Rate Initial Production (LRIP) phase. The F/A-18 E/F like-components will tested on the STS. The software and hardware adaptations required for the bench to meet these needs is being accomplished at H.R. Textron in Los Angeles, California.

A list of F/A-18 components currently being tested on the STS is presented in Figure 3. The work unit codes (WUC), nomenclatures, and actual descriptions are provided. The TEF/HS is produced by Parker Bertea Aerospace, Parker Hannifan Corporation. In addition to Parker Hannifan producing the TEF/HS for the F/A-18,

| WUC | Nomenclature | Description |
|---|---|---|
| 13C6210 | NWS, HPU | Nose Wheel Stg Hydr Unit |
| 1421210 | Aileron, HS | Aileron Actuating Hydr Servocylinder |
| 1431210 | Stabilizer, HS | Horiz Stabilizer Hydr Servocylinder |
| 1441210 | Rudder, HS | Rudder Hydr Servocylinder |
| 1451310 | LEF, HDU/HSA | Drive Unit and Servocylinder assembly |
| 1451311 | LEF, HDU[1] | Leading Edge Flap, Drive Unit assembly |
| 1451312 | LEF, HSA[1] | LEF , Servovalve assembly |
| 1451900 | LEF, HSA-REM | LEF, Hydr Servovalve Assy-Remote |
| 1461210 | TEF/HS | Trailing Edge Flap Hydr Servocylinder |

**Figure 3. F/A-18 Hydraulic Components Serviced on the STS**

**Note 1**: All components are weapons replaceable assemblies (WRA) except 1451311 and 1451312, which are shop replaceable assemblies (SRA) for 1451310.

they are producing the TEF/HS for the F/A-18 E/F. The other hydraulic components listed are produced by several other subcontractors on the F/A-18 program.

Hydraulic components repaired and tested on the STS have experienced long periods of awaiting parts (AWP) and excessive BCM rates. The original MTBF estimates were grossly overestimated. This adversely affects the availability of

spares, subcomponents and piece parts availability. MTBF can be improved through product improvement initiatives and maintenance training. BCM's have also been significantly higher than estimated. BCM's may be reduced in a variety of ways. Two methods to decrease BCM rates include, acquiring increased depth of repair authorization and pooling the organic technical expertise at the intermediate level to increase the repair capability. However, Naval Aviation Depot (NADEP) North Island has been resistant to grant approval in the area of increased depth of repairs at the intermediate level because of the high level of expertise and tooling required. NADEP and the original equipment manufacturer (OEM) currently conduct these "increased expertise" repairs on actuators upon receipt of the BCM asset. The Navy and Marine Corps technical expertise is not pooled with the depot technicians, but rather is split between the four PIMA's and additional splinter IMA's.

***b. Trailing Edge Flap, Hydraulic Servovalve***

The McDonnell Douglas Aircraft (MDA) and Northrop team was selected to build the Northrop originated F/A-18 design in the mid-1970's. Extensive engineering and manufacturing design at the subcontractor level began to meet the procurement requirements. The Bertea Corporation, which later was purchased by the Parker Hannifan Corporation, began work on the original TEF/HS.

In accordance with the MDA procurement specification for the TEF/HS, ten dash numbers have been issued since the beginning of the program in October 1974.

Parker Hannifan issued two top assembly part numbers for the TEF/HS; the early version P/N 268100 (with five dash numbers) and the production P/N 287800 (also with five dash numbers).

The early 268100 TEF/HS's consisted of the dual hydraulic, quad electric channel fly by wire system featured in the later TEF/HS's, but did not feature the zero degree hydraulic lock position of the current TEF/HS's. In case of complete electric failure, the early TEF/HS's had a detent spring load on the Main Control Valve spool which would position the spool to fully retract the actuator at a controlled rate to the faired position. Not many 268100 TEF/HS's were built. Parker Hannifan's Customer Support Office (CSO - Repair facility) has received only two of this model in the past six years. My research at Parker Hannifan Corp. reveals they were used on F/A-18A's flown by NASA. Regardless, whenever a 268100 is received, a request for scrap is sent to the Navy Inventory Control Point (NAVICP). There is no repair contract in place for the 268100 and there are no detail parts provisioned for this model TEF/HS.

Flap travel requirements changed with the different part numbers and dash numbers. The 287800 TEF/HS's incorporated the basic operational functions of the earlier 268100's with the addition of a fail safe zero degree hydraulic lock position mode selector. The flap travel had evolved from an actuator full retracted/flap zero degree, to full extended/flap 20 degree down travel to an actuator full retracted/flap

eight degree up to full extended/flap 45 degree down travel. Instead of having the TEF/HS fail into a retracted position, equivalent to eight degrees up on the later TEF/HS's, the requirement changed to have a quad electric channel failure hydraulically lock to the zero degree (or faired) position.

This required the addition of a spring loaded selector valve, the mode selector, which when the solenoids are energized allowed the main ram actuator to follow the command of the Main Control Valve (which in turn is controlled by the Electro Hydraulic Servo Valves - EHV's); in essence allowing the actuator to be controlled by wire (CBW) from the Flight Control Computer (FCC). When all four channels of the solenoids from both hydraulic systems are shut off, the spring loaded mode selector valve cuts off the flow from the main control valve to the main ram actuator and opens up the flow passage of a hole in the side of the main ram cylinders. The main ram moves towards this position at a rate controlled by upstream and downstream orifices. Once at this position a hydraulic lock is obtained.. One innovative design feature required to make this requirement a reality was the design of a hard plastic piston head seal which could stroke over a sharp edged hole millions of cycles and not fail. This design feature is not incorporated in any other Parker Hannifan flight control/actuator - military or commercial. This zero lock feature was added to the TEF/HS, resulting in the 287800 part number in 1980. Four dash

numbers were used on the 287800, finally settling on the 287800-1005 configuration for large scale production in 1981. This unit was produced in large numbers - over 2500 units by 1993.

An intermediate level technical manual was delivered in 1984, however it contained only limited information regarding intermediate level repairs and did not include repair guidelines for detail parts. Depot level repairs were performed at Parker Hannifan Corp.

The 287800-1005 TEF/HS's experienced high failures resulting from heavy wear on the piston heads and cylinder walls of the actuator. A large number of pistons and cylinders were being scrapped and extensive salvage procedures were implemented to keep up with the demand for TEF/HS's. A review of the environmental conditions which the TEF/HS operated in, revealed a 28 Hz wind load on the TEF surface was being driven back into the TEF/HS causing a dither, which when combined with a two degree load offset from the actuator main axis, caused the excessive wear on the pistons and cylinders. This is more commonly referred to as the 'side loading' problem. A redesign of the actuator ensued, with main change being an increase in the amount of contact area of the piston head. This new configuration is P/N 287800-1009 and is being incorporated by attrition under engineering change proposal (ECP) 315.

In addition to the mechanical failures mentioned above, the TEF/HS has suffered a high incidence of single channel BLIN code rejections from the aircraft. ECP 315 was not designed to address this issue. Intermittent high temperature Controlled By Wire (CBW) and Fail Sensor Linear Variable Differential Transformer (LVDT's discussed in detail below) transducers short circuited when the room temperature resistance measured greater than 100 megohms. This was identified in 1991 as being a failure mode particular to the LVDT produced by Kavlico Corporation. LVDT's have been produced by three companies, Kavlico, G.L. Collins and the G.W. Lisk Company.

Kavlico, who manufactured the overly temperature sensitive LVDT's, unfortunately produced the majority of the LVDT's used on TEF/HS's. The LVDT's failed under high temperature conditions at a 30% rate as measured by the Cognizant Field Activity (CFA) and Parker Hannifan. Two upgraded versions were produced. The first iteration produced a reduction in the failure rate and the final iteration has not produced a failure to date.

### c. *TEF/HS Testing on the STS*

The Servocylinder Test Station (STS) gives incorrect readings for the CBW LVDT voltage. The STS CAS (CBW) Null LVDT voltage reading is a factor of more than five times less than the actual servocylinder voltage. A Test Work Around Procedure (TWP) was issued on 24 January 1995 that directs STS operators

to perform the test under the tighter limits, thus *accommodating* the incorrect reading.

This test work around procedure is one of 13 primary TWP's on the STS. STS operators receive a Test Results printout for each procedure performed by the STS for each unit under test. The words Pass or Fail are printed under each specific test designating the specific test result. In the case of this TWP, the operator cannot rely on the Test Results Printout. The printed word *Pass* may not be correct. The operator must recheck the '*Pass*' values with the TWP parameters to determine if it is within limits. Although the use of TWP's is common with Automatic Test Equipment (ATE) because the cost of software upgrades precludes frequent updates, the lack of a STS software upgrades adds a great deal of confusion and uncertainty.

### *d. Linear Variable Differential Transformer (LVDT)*

An LVDT is a transducer that converts a linear displacement into an electrical output signal which can be used to measure position, velocity and acceleration. The LVDT consists of a primary transformer coil wound on a nonmagnetic cylindrical coil form. Two secondary transformer coils are wound on top of the primary. This coil assembly is then installed in a mechanical housing. The other major component is ferromagnetic core moving inside the coil form.

In operation, the primary coil is charged with a sine wave of alternating current. This creates an axial magnetic flux field which is concentrated in the core.

This flux is coupled to the secondary windings through the core, inducing an output voltage in each secondary winding.

When the core is centered between the two secondary windings the voltage induced in each is identical. The voltage induced in each secondary will be in phase with the excitation voltage. The vector difference between each secondary voltage will be zero. The core position where the voltage difference is zero is referred to as the null position.

When the core is moved in either direction from the null position, the amplitude of the secondary voltage difference changes in direct proportion to the displacement. But the phase relationship with the excitation also changes. In one direction the output signal will be in phase with the excitation and 180 degrees out of phase in the other direction. The output voltage therefore has two components: (1) amplitude indication the magnitude of the displacement and (2) phase relationship indicating direction of displacement.

## C. COMPLEXITY OF THE STS AND TEF/HS

As outlined above, the complexity of electronic flight controls and the STS has evolved exponentially from the mechanical hydraulic actuators of yesterday. A great deal of focus has been placed on the complexity of this specific intermediate repair for the F/A-18 evidenced partly by Naval Air Systems Command (NAVAIR) creating the Hydraulic Action Team (HAT) to examine the intricacies in this area.

Additionally, NAVAIR employs on-site STS Contractor Engineering Technical Specialists (CETS) and STS Navy Engineering Technical Specialists (NETS) in Lemoore, Cecil, Beaufort and Miramar. Additional ETS are available onsite the four F/A-18 prime sites to provide engineering support for the actuator repair. The difficulties in maintaining this system has made it imperative to maintain a high level of organic and core expertise.

# III. DEVELOPMENT OF THE MODEL

## A. THE POWER OF SPREADSHEETS

### 1. Spreadsheets

Spreadsheets have become a popular tool for managers to evaluate a multiple inputs and create outputs as a decision support tool. Vazsonyi (1993) provided a journal article that details the power and potential of spreadsheets for today's manager. Spreadsheets provide a mechanism for managers to avoid classical mathematics and approximate solutions to their problems through elementary numerical analysis. For example, Kang (1993) developed spreadsheet based decision support model that can evaluate fleet readiness under various logistics support scenarios, particularly in spare parts management.

In this thesis we utilize Quattro Pro spreadsheets to develop a model for comparative analyses and graphical displays. The desktop spreadsheet tool provides a medium to evaluate measures of effectiveness for the proposed consolidation to a Super Hydraulic "I" Level. The areas evaluated are AVDLR and AOM costs, transportation, manpower, spares, product improvements and facilities and relocation costs.

## B. AVDLR AND AVIATION OPERATIONS MAINTENANCE (AOM)

### 1. Aviation Depot Level Repair Charges

Repairables incur a flat-rate AVDLR charge when they are shipped from the intermediate level of maintenance to the depot level of maintenance. If the retrograde asset is turned-in to the depot along with the requisition, the repairable cost is charged. The replacement cost is applied for the acquisition of new TEF/HS's or in the event the retrograde is not turned-in to depot (e.g., missing, lost or stolen repairable). The TEF/HS costs are shown in Figure 4.

| WUC | Part Number | Nomenclature | Replacement Cost | Repairable Cost |
|---|---|---|---|---|
| 1461210 | 287800-1009 | TEF/HS | $100,740 | $15,350 |

**Figure 4. Trailing Edge Flap, Hydraulic Servovalve Cost Data**

The number of AVDLR's that are BCM to the depot is available in the Naval Aviation Logistics Data (NALDA) database. For modeling other than the actual parameters, AVDLR's BCM to depot can be modeled with the availability or projection of the following data: failures (or MTBF), flight hours, aircraft utilization, number of aircraft and BCM rate. Aircraft (AC) baseloading and utilization for this thesis were taken from the F/A-18 Weapons System Planning Document (WSPD) (Ser Air-1.3.3.5 dated 21 March 1995). As depicted in the WSPD, flight hours for each

aircraft are estimated at 35 hours/month (1.17 hours/day) and AC baseloading is as follows: NAS Lemoore - 158, MCAS Miramar - 117. The actual aircraft assigned to each site may be higher than the value listed in the WSPD. The number in the WSPD is for planning purposes and accounts for dynamic characteristics such as operational aircraft that receive intermediate level support from other than their *homeport* facility when they deploy.

### 2. AVDLR BCM Model

We develop an AVDLR BCM model that can determine the number of BCM actions and associated AVDLR charges assessed at different BCM rates. This model can be illustrated by providing the following simple example. If a component on your car has an MTBF of 100 hours and you operate your car two hours per day, the component is expected to fail an average of once every 50 days. If you own two cars, both with the same characteristics and usage, you would expect an average of two failures every 50 days or an average of one failure every 25 days. Since the AC utilization is only 1.17 hours per day, the MTBF must be transformed to the measure based on a 24 hour day. Conversion to hours is accomplished by applying a factor of 24. Using this logic the following formula can be applied to generate the MTBF of failed TEF/HS's at the intermediate maintenance level:

$$\mathbf{m = [24* (\lambda^{-1} \div U)] \div n}$$

m - Mean Time Between Arrival (MTBA) to the IMA (hours)

$\lambda$ - Verified Failures / Total Flight Hours

$\lambda^{-1}$ - MTBF (hours)

U - Aircraft Utilization/Day

n - Total number of TEF/HS (Total AC * 2)

The mean time between arrivals to the IMA (m) can be divided into the total hours per year to provide the failures per year. The number of failures per year multiplied by the BCM rate and the AVDLR cost provides the AVDLR annual costs.

Figures 5a and 5b show the effects of the two BCM rates and three MTBF values at NAS Lemoore and MALS-11 respectively. Two BCM rates are evaluated in this thesis. The TEF/HS's current BCM rate (39%), obtained from 1995 historical data, is compared with the original design BCM rate (17%). The original design BCM rate was obtained from the Aviation Support Office (ASO). The three MTBF values used in Figures 5a and 5b are the CY1995 actual value, the projected MTBF and the TEF/HS original design MTBF. The MTBF values are discussed in greater detail in Section F. Figures 5a and 5b outline the relationship between MTBF and BCM rates on AVDLR rates. The cost figures are intended to show the relationships of the variables, not projected annual savings.

| | MTBF - 201 hours | MTBF - 409 hours | MTBF - 2,174 hours |
|---|---|---|---|
| MTBA - AIMD Lem | 13.1 | 26.6 | 141.5 |
| Failures/Yr - AIMD | 669 | 329 | 62 |
| AVDLR$ - BCM 17% | $1,745,755 | $858,526 | $161,528 |
| AVDLR$ - BCM 39% | $4,004,969 | $1,969,559 | $370,564 |

**Figure 5a. NAS Lemoore AVDLR Cost Comparison for Actual, Projected and Original MTBF's and Actual and Original BCM Rates (Note: MTBA- Mean Time Between Arrival)**

| | MTBF - 201 hours | MTBF - 409 hours | MTBF - 2,174 hours |
|---|---|---|---|
| MTBA - MALS 11 | 17.7 | 36.0 | 191.1 |
| Failures/Yr - MALS 11 | 495 | 244 | 46 |
| AVDLR$ - BCM 17% | $1,291,703 | $635,674 | $119,515 |
| AVDLR$ - BCM 39% | $2,028,825 | $1,458,311 | $274,182 |

**Figure 5b. MALS-11 AVDLR Cost Comparison for Actual, Projected and Original MTBF's and Actual and Original BCM Rates (Note: MTBA- Mean Time Between Arrival)**

## C. TRANSPORTATION COSTS

The consolidation of AIMD Lemoore and MALS-11 for the intermediate level repair of TEF/HS's will require a transportation pipeline between the two locations. The Navy supply system is already in place and could provide the requisite shipping and receiving. However, the Navy supply system exhibits a high degree of variability. For the models used in Chapter IV, the Navy supply system was

estimated at three days (one way). Based on our experience we estimated the majority of actual shipping times range from one to five days with an equal probability for each occurrence. The readiness and spare levels required to warrant the Super Hydraulic "I" Level are directly linked to the customer service level of transportation in this pipeline. The investment in the increased service level provided by a dedicated transportation source is justified by the savings in safety stock spares and increased readiness which is described in Section E. Figure 6 represents the worst case annual transportaion costs between Lemoore, California and San Diego, California (6 days per week for 52 weeks). Figure 7 is a sample of one-way transportation cost estimates between Lemoore and San Diego (source: NAS Lemoore Shipping and Receiving Division).

| **Worst case LTL (6 days/week)** | **Worst case TL (6 days/week)** |
|---|---|
| $182,064.48 per year | $295,981.92 per year |

**Figure 6. Worst Case Shipping Costs Between Lemoore and San Diego**

| **LTL/500lb minimum (one way)** | **Lemoore to Miramar** |
|---|---|
| High | $488.00 to $583.54 |
| **TL/25,000lb minimum (one way)** | **Lemoore to Miramar** |
| High | $863.00 to $948.66 |

**Figure 7. Transportation/Shipping Costs Between MCAS Miramar and NAS Lemoore**

## D. MANPOWER

Both the Navy and the Marine Corps' PIMA's possess unique manpower requirements and characteristics. Both the Navy and the Marine Corps PIMA's are staffed with intermediate level technicians who simultaneously deploy with the organizational technicians and squadron F/A-18 aircraft from their respective bases. When the aircraft are not on deployment and are receiving intermediate support from their respective PIMA, these technicans augment the shore-based intermediate level manning to offset the increased workload from *their* aircraft's operations and also to maintain proficiency for the ensuing deployment.

The Navy refers to these aforementioned technicians as the Sea Operational Detachment (SEAOPDET). This cadre of techicians is assigned to provide intermediate level support for F/A-18 squadrons deploying onboard aircraft carriers. The SEAOPDET augments the core technicians assigned to the PIMA or the core technicians assigned to the aircraft carrier IMA based on the aircraft's source of intermediate level support. The Marine Corps MALS maintains a similar cadre of intermediate level techicians that differ from the SEAOPDET only in that they augment their deployable Aircraft Combat Elements (ACE) in addition to aircraft carriers.

In view of the unique nature of the staffing at both the Navy and the Marine Corps intermediate sites, the current level from each site will be assigned in their

entirety at the Super Hydraulic "I" Level site. This consolidation of skill levels provides a better resouce allocation by *pooling* resources. The consolidation of manpower can be completed through attrition of billets at the closed site and their subsequent reassignment to the Super Hydraulic "I" Level. This will preclude a one-time manpower relocation cost.

## E. SPARES

The allowance of spares at the two west coast PIMA's is shown in Figure 8. The current availability of these assets is universally zero. For example, the outstanding TEF/HS documents at Lemoore has ranged between 37 and 45 over the past year (source: CSFWP F/A-18 Class desk). Of these 37 - 45 documents, 19 account for the authorized allowance for spares. The remaining balance of the documents are for between 18 and 26 aircraft (between 9 and 13 aircraft allowing for failed TEF/HS documents to be paired in the same aircraft) that are Not Mission Capable (NMC) solely as a result of the TEF/HS. Using this data with Lemoore's WSPD baseloading figure of 156 aircraft, the reduction in readiness from the TEF/HS alone ranges from 12% to 17%. These outstanding documents are comprised of the backlog at AIMD and depot repair facilities. The TEF/HS zero spares balance and aircraft readiness can be addressed in three ways.

| Location | TEF/HS Allowance | Stock Level (5/22/96) |
|---|---|---|
| NAS Lemoore | 19 | 0 |
| MCAS Miramar (El Toro) | 33 | 0 |
| NAS Fallon | 3 | 0 |

**Figure 8. TEF/HS Spares Allowances and Availbility at NAS Lemoore and Fallon and MCAS Miramar**

First, additional spares can be purchased to provide the increased protection level. The cost of each spare is $100,740 as shown in Figure 4. Second the turnaround (TAT) time between the time of the component failure and its return to service must be reduced. The TAT for the depot is contracted with the NAVICP at 44 days. The TAT at the intermediate level ranges from 1 to 60 days. A component that is AWP becomes eligible for a BCM due to lack of replacement parts at 60 days. Based on these numbers, we have estimated a discrete value of 31.5 days TAT at the "I" level [(60 + 1) ÷ 2]. Lastly, the MTBF can be increased to reduce the number of failures entered into the repair process. This last option is a design issue and is tangent to this thesis. The impact of the proposed MTBF increases will be addressed for each scenario to show the additional impact.

## F. PRODUCT IMPROVEMENTS AND MTBF

MTBF was calculated from two independent McDonnell Douglas and Parker Hannifan analyses (documented in a preliminary report from Parker Hannifan dated 17 January 1996) tracking the performance of a group of 150 TEF/HS's that were

manufactured after the incorporation of the most recent upgrade involving LVDT product improvements. The failure rates projected by each analysis were an MTBF of 404.6 hours and 414.2 hours respectively. We will use the MTBF of 409 ([404.6 + 414.2]/2) for the projected MTBF rate in the analysis. This projected MTBF value will be compared with the current MTBF of 201 hours calculated from 1995 data, and the TEF/HS's original design MTBF (2,174 hours) obtained the Aviation Support Office (ASO).

## G. FACILITIES AND RELOCATION

The 1993 Base Realignment Comission mandated the relocation of MCAS El Toro to NAS Miramar. The tranisition between El Toro and Miramar is ongoing and is targeted for completion October 1996. The Marine Corps intermediate maintenance concept is predicated on its capability to rapidly deploy. To facilitate this need, the majority of the Marine Corps ATE is maintained and operated out of mobile maintenance facilities, also referred to as deployable vans. Conversely, the Navy hardsites its ATE and in many instances, including the STS, maintains dual ATE capability at the air station and on the aircraft carrier. In view of this, the facility costs can be disregarded as sunk costs because existing facilities at Miramar have excess capacity and can be utilized to satisy the space requirements of the Super Hydraulic "I" Level. The relocation, setup and calibration of the STS assets from Lemoore and Miramar can be estimated at a fully burdened rate of approximately

$10,000 based on the costs incurred to setup and calibrate an STS bench at NAS Lemoore (Source: LCDR Martin Jones, AAMO, AIMD Lemoore).

## H. TEF/HS OPERATIONAL AVAILABILITY MODEL

We modified the base model to represent three scenarios NAS Lemoore's F/A-18 aircraft and PIMA, MALS-11 aircraft and PIMA and the Super Hydraulic "I" Level supporting aircraft from both sites.

The advantages of this model are its ability to show the discrete relationships and sensitivities of the input variables. The disadvantage of this model is that it does not take the variability of the inputs into account (i.e., the TAT time for depot repairs is a fixed value of 44 days). In reality, the TAT time for depot repairs does not consistently occur at its mean of 44 days. The repair times follow a distribution of values with a distinct range and characteristics. Utilizing the actual distributions to represent the respective processes significantly affects the outcome.

Figure 9 shows the relationships of the base model. The model was modified to accommodate the Super Hydraulic "I" Level by including the shipping time from the Super "I" in San Diego, California to the aircraft in Lemoore, California.

| | |
|---|---|
| a. Number of Aircraft Supported | x |
| b. MTBF | $\lambda^{-1}$ |
| c. BCM Percentage | $\beta$ |
| d. Depot Turnaround Time (TAT) | D |
| e. Intermediate Level TAT | I |
| f. Shipping Time "D" to "I" | s |
| g. Number of Spares | n |
| h. TEF/HS Operational Availability NOTE: (**f** = TEF/HS failures) | $[((n + 2x) \cdot 8{,}760)] - [(\mathbf{f} \cdot D \cdot \beta) + (f \cdot s \cdot \beta) + (f \cdot (1 - \beta) \cdot I)] \div [(2x \cdot 8{,}760)]$ |
| i. Total BCM TEF/HS | $[(2x \cdot 420) / \lambda^{-1}] \cdot \beta$ |
| j. AVDLR Charges ($) | Tot BCM · $15,350 |
| k. Spare Parts Pool Balance (>0) | n - (2x) - [(TEF/HS Operational Availability) ÷ [(2x · 8,760)] * 2x] |
| l. Aircraft TEF/HS Readiness (<100%) | (2x + n + Spare Parts Pool Balance)/2x |

**Figure 9. Sample Spreadsheet TEF/HS Operational Availability Model**

- Rows a - g are the model's cells for the input data and are self explanatory.
- Row h can be described using the following example: Assume your car is available 168 hours per week. Also, it requires maintenance and not available for 84 hours of that same week. Your cars operational availability for that week would be (168 - 84) ÷ 168 = 50%. Row h can be further broken down as follows: [(Total Hours Available incl. Spares) - (Total Time not available)] ÷ [Total Hours Available]. The Operational Availability has been transformed

to a measure based on annual values. The constant 8,760 represents the total hours per year.

- Row i takes the total number of failed TEF/HS's and multiplies that value by the BCM percentage. This provides the total BCM assets. The constant 420 represents the number of hours one aircraft flies per year - 35 hours per month multiplied by 12 months.
- Row j uses the total number of BCM assets and the depot AVDLR charge to provide the total AVDLR charges.
- Row k utilizes the value from row h to calculate the number of assets needed from the spares pool.
- Row 1 calulates the aircraft readiness as a percentage of the available TEF/HS's compared with two TEF/HS's per aircraft (a full complement).

This model will provide the primary tool for our analysis in the following chapter.

# IV ANALYSIS

## A. BCM RATES AND MTBF

The reductions in BCM rates and increase in MTBF improve readiness and reduces AVDLR spending. Increasing MTBF is primarily a design issue and potentially entails costly engineering studies and retrofits. However, improving readiness by lowering the BCM rates is cost saving venture. The intermediate levels do not spend the $15,350 AVDLR cost required to BCM a component. Depot facilities charge a flat rate of $15,350 to account for their complete overhaul costs of the component. The intermediate level does not perform complete overhaul. Malfunction codes on the CY1995 failures reveal the majority of the repairs at the intermediate level entail repairing leaks that require packings, seals and "O" rings that are low cost consumable items. The AVDLR charge and intermediate level repair costs (AOM) are paid for from the same appropriation. It is widely accepted that repairs at the intermediate level cost less than the AVDLR charge. To quantify the intermediate level repair costs is difficult because of the accounting and documentation at the intermediate level. For example, not all intermediate level subcomponents and piece parts are ordered against a specific component. They are purchased in bulk and allocating these costs to components is beyond the scope of this thesis. New intermediate level cost accounting systems are being developed to address this issue (Naval AIMD Cost Accounting (NACA) system).

Secondly, readiness can be improved by dealing with the TAT from the time the component fails to the time a replacement component is installed. For example, the number of components in the repair pipeline has exceeded the availability of spares at NAS Lemoore and MALS-11 for over 18 months (NAVICP, Ms. Sue McGuinn, March 1996). The effects of shortening the repair pipeline are increased readiness and a reduced requirement for spares.

## B. CONSOLIDATION AND AVDLR CHARGES

The reduction in BCM rates proportionally reduces Aviation Depot Level Repairable charges (AVDLR). Achieving this reduction can be accomplished by improving the technical expertise of personnel, increased depth of repair and greater availability of subcomponents and piece parts. Consolidation will result in improvements in each of these areas by pooling the manpower, skill level and subcomponent and piece part resources. This is outlined in Figures 10, 11 and 12. Figures 10 and 11 represent the Lemoore and MALS-11 aircraft and PIMA's respectively under existing conditions. Figure 12 represents a consolidated Super Hydraulic "I" Level supporting the aircraft from both sites. Figure 12 assumes the estimated benefits of consolidation. In Figure 12 we reduce the BCM percentage to 17%, reduce depot TAT to 24 days (Mr. Stephen Gustin, NADEP North Island, Production Manager's estimate of depot TAT time under stated conditions), reduce intermediate TAT to 20 days (based on our estimate from the pooling of resources) and utilize the combined allowance for spares from each site. Under the stated conditions of this

model in Figures 10, 11 and 12, the consolidation from two separate PIMA's to the Super Hydraulic "I" Level provides a potential AVDLR savings of $3,881,029.

The TEF/HS's operational availability is shown in Figures 10, 11 and 12. The operational availability of TEF/HS's can provide aircraft readiness and spares availability. For instance, the Lemoore example in Figure 10 shows an operational availability for TEF/HS's, including spares, of 84%. This operational availability reflects 49 TEF/HS's not available (84% of 316 TEF/HS's). 49 TEF/HS's would deplete the pool of 19 and also result in the downing of 30 aircraft (15 aircraft allowing for failed TEF/HS's to be paired in the same aircraft). Because of the complexity and risk of cannibalization, we do not pair failed components on one aircraft. The spares pool at MALS-11 is based on 14 spares. 14 spares is the based on the ratio of aircraft at each site and 19 spares at NAS Lemoore.

| | |
|---|---|
| ***Navy Inputs*** | |
| **# Navy A/C NASL** | **158** |
| **MTBF** | **201** |
| **BCM %** | **39%** |
| **"D" TAT (hrs)** | **1056** |
| **"I" TAT (hrs)** | **756** |
| **Shipping time "D" to "I"** | **144** |
| **# Navy Spares** | **19** |
| | |
| ***Outputs*** | |
| **TEF/HS Oper Avail (Navy)** | **78%** |
| **Total BCM to Depot** | **258** |
| **AVDLR Charges** | **$3,952,877** |
| **Spare Parts Pool Balance** | **0** |
| **Aircraft TEF/HS Readiness** | **84%** |

**Figure 10. NAS Lemoore**

| | |
|---|---|
| *Marine Corps Inputs* | |
| # USMC A/C MALS-11 | 117 |
| MTBF | 201 |
| BCM % | 39% |
| "D" TAT (hrs) | 1056 |
| "I" TAT (hrs) | 756 |
| Shipping time "D" to "I" | 144 |
| # USMC Spares | 14 |
| | |
| *Outputs* | |
| TEF/HS Oper Avail (MC) | 78% |
| Total BCM to Depot | 191 |
| AVDLR Charges | $2,927,130 |
| Spare Parts Pool Balance | 0 |
| Aircraft TEF/HS Readiness | 84% |

**Figure 11. MALS-11**

| | |
|---|---|
| *Super Hyd "I" Inputs* | |
| # A/C MALS-11 & NASL | 275 |
| MTBF | 201 |
| BCM % | 17% |
| "D" TAT (hrs) | 576 |
| "I" TAT (hrs) | 480 |
| Shipping time "D" to "I" | 144 |
| Trans time - Super to NASL | 24 |
| # MALS 11 & NASL Spares | 33 |
| | |
| *Outputs* | |
| TEF/HS Oper Avail (Super) | 87% |
| Total BCM to Depot | 195 |
| AVDLR Charges | $2.998M |
| Spare Parts Pool Balance | 0 |
| Aircraft TEF/HS Readiness | 93% |

**Figure 12. Super Hydraulic "I" Level**

Although MALS-11 has a total of 33 spares, the additional spares are available for pack-up kits to accommodate rapid deployment of the ACE's. To rationalize this inequity of spares between sites, the Navy's balance of spares are located on deployed carriers.

In the Super Hydraulic "I" Level 93% of the TEF/HS's are operationally available or 39 TEF/HS's not available. These 39 TEF/HS's would deplete the spare component pool of 33 spare assets and would degrade six aircraft (three aircraft allowing for failed TEF/HS's to be paired in the same aircraft).

Lemoore would have to purchase 30 additional spares and MALS-11 would have to purchase 21 additional spares to increase their respective Aircraft TEF/HS Readiness rates to the 93% shown in the Super "I" in Figure 12. This would cost $5,137,740 to purchase the additional 51 spares.

Figures 13, 14 and 15 show the same relationships as above with the proposed increase of MTBF to 409 hours included. The increase in MTBF produces profound effects on each of the models - single PIMA's and the Super "I". Under the stated conditions of this model in Figures 13, 14 and 15, the consolidation from two separate PIMA's to the Super Hydraulic "I" Level provides a potential annual AVDLR savings of $1,907,303.

The values from Figures 10-15 are further evaluated in a NPV analysis that is provided in Appendix B. This analysis identifies the discrete savings under the stated conditions and assumptions. Figure 16 contains a summary of the NPV analysis showing a potential $42M of savings (discounted at 10%) over a 10 year life cycle. The Additional

Spares Reduction under the *Design Improvements* represents the reduction of 17 spares at the Super "I" while maintaining a 97% Aircraft TEF/HS Readiness.

| | |
|---|---|
| *Navy Inputs* | |
| # Navy A/C NASL | 158 |
| MTBF | 409 |
| BCM % | 39% |
| "D" TAT (hrs) | 1056 |
| "I" TAT (hrs) | 756 |
| Shipping time "D" to "I" | 144 |
| # Navy Spares | 19 |
| | |
| *Outputs* | |
| TEF/HS Oper Avail (Navy) | 89% |
| Total BCM to Depot | 127 |
| AVDLR Charges | $1,942,612 |
| Spare Parts Pool Balance | 0 |
| Aircraft TEF/HS Readiness | 95% |

**Figure 13. NAS Lemoore**

| *Marine Corps Inputs* | |
|---|---|
| # USMC A/C MALS-11 | 117 |
| MTBF | 409 |
| BCM % | 39% |
| "D" TAT (hrs) | 1056 |
| "I" TAT (hrs) | 756 |
| Shipping time "D" to "I" | 144 |
| # Marine Corps Spares | 14 |
| | |
| *Outputs* | |
| TEF/HS Oper Avail (MC) | 89% |
| Total BCM to Depot | 94 |
| AVDLR Charges | $1,438,516 |
| Spare Parts Pool Balance | 0 |
| Aircraft TEF/HS Readiness | 95% |

Figure 14. MALS-11

| *Super Hyd "I" Inputs* | |
|---|---|
| # A/C MALS-11 & NASL | 275 |
| MTBF | 409 |
| BCM % | 17% |
| "D" TAT (hrs) | 576 |
| "I" TAT (hrs) | 480 |
| Shipping Time "D" to "I" | 144 |
| Ship Time Super to NASL | 24 |
| # MALS 11 & NASL Spares | 33 |
| | |
| *Outputs* | |
| TEF/HS Oper Avail (Super) | 94% |
| Total BCM to Depot | 96 |
| AVDLR Charges | $1,473,825 |
| Spare Parts Pool Balance | 0 |
| Aircraft TEF/HS Readiness | 100% |

Figure 15. Super Hydraulic "I" Level

| *Super "I" Savings* | NPV |
|---|---|
| Total (undiscounted) | $36,970 |
| Discounted Total (10%) | $22,709 |
| | |
| *Design Improvements* (MTBF) | |
| Total (undiscounted) | $32,380 |
| Discounted Total (10%) | $19,896 |
| | |
| *Combined Total Savings* | |
| Total (undiscounted) | $69,350 |
| Discounted Total (10%) | $42,604 |

**Figure 16. Net Present Value Savings Analysis in Thousands ($)**

These savings can be adjusted according to the target readiness requirements. Manpower will not be downsized or relocated. As stated in Chapter 3, we propose the billets be relocated by attrition, thus eliminating the one-time relocation costs.

# V. CONCLUSIONS

## A. FINDINGS

This thesis provides an analysis of the consolidation of hydraulic intermediate maintenance capabilities for the Trailing Edge Flap, Hydraulic Servovalve (TEF, HS). The following conclusions have been reached:

### 1. Consolidation and AVDLR Savings

The TEF/HS and Servocylinder Test Station (STS) are complex equipments that are significant contributors to the degradation of F/A-18 readiness. The related hydraulic components tested on the STS share similar characteristics. Scarce resources and expertise have further complicated this issue. Consolidation of the prime intermediate maintenance sites on the west coast will provide a mechanism to reduce intermediate and depot TAT and BCM rates. A reduction in BCM to 17%, coupled with decreasing the depot and intermediate TAT, as shown in Figure 12, could save AVDLR charges in excess of $3.8 million per year. As discussed in Chapter 3, the model and the resulting cost savings are intended to outline interrelationships and sensitivities of the key variables affected in consolidation.

### 2. The TEF/HS and Product Improvement Investment

The TEF/HS has not met its intended reliability requirement. All planning was predicated on a Mean Time Between Failure (MTBF) of 2,174 hours. However the

component maintained an MTBF of 201 hours in calendar year 1995. Parker Hannifan, in concert with McDonnell Douglas and the Navy, has recognized the need to invest in reliability improvements.

### 3. The F/A-18 E/F May Demonstrate Similar Traits

F/A-18 readiness problems partly stem from the failure of components to meet their planned MTBF's. The TEF/HS was designed and tested to have an MTBF of 2,174 hours. It has realized a MTBF of 201 hours in 1995. The next generation TEF/HS for the F/A-18 E/F is very similar in engineering, design and function and being developed by the same contractor.

## B. RECOMMENDATIONS

### 1. Consolidation and AVDLR Savings

We recommend that the Navy and Marine Corps consolidate, in their entirety, the intermediate maintenance hydraulic capabilities of AIMD Lemoore and MALS-11 in San Diego, California at MCAS Miramar. The potential savings from a Super Hydraulic "I" Level is $42M (discounted at 10%), and is needed for product improvement initiatives.

### 2. The TEF/HS and Product Improvement Investment

The contractor must be held accountable to meet the projected MTBF of 409 or higher upon completion of the Linear Variable Differential Transformer (LVDT) upgrade. This upgrade should be viewed as the interim step toward a product improvement that returns the TEF/HS to its originally contracted MTBF - 2,174 hours.

### 3. The F/A-18 E/F May Demonstrate Similar Traits

The contract for the F/A-18 E/F TEF/HS should be designed to ensure the contractor is held accountable for their projected MTBF. Parker Hannifan, MDA and the Navy-Marine Corps accepted the current TEF/HS's MTBF of 2,174. The F/A-18 E/F's proposed TEF/HS MTBF has to be challenged to preclude the replay of the F/A-18 C/D's dramatic TEF/HS shortfall.

## C. FINAL REMARKS

Downsizing and fiscal constraints are a current reality faced by the all DoD agencies. The impact of joint programs, regional consolidations, and privatization are focused on meeting these fiscal demands. Each of these approaches must heavily weight the impact on readiness. This consolidation of hydraulic maintenance facilities for F/A-18 hydraulic components is only a very small part of the big picture. Nevertheless, it is the aggregate implementation of concepts like this, through the use of comparative spreadsheet analysis, that will reduce the adverse impacts on readiness and allow us to face the continuing reality of decreasing budgets.

# APPENDIX A

## Acronyms

AIMD - Aircraft Intermediate Maintenance Department

ASO - Aviation Support Office

ATE - Automatic Test Equipment

AVDLR - Aviation Depot Level Repairable

AWP - Awaiting Parts

BCM - Beyond Capability of Maintenance

CBW - Controlled By Wire

CETS - Contractor Engineering Technical Specialists

CFA - Cognizant Field Activity

CNO - Chief of Naval Operations

CSO - Customer Support Office (Parker Hannifan Corp.)

DoD - Department of Defense

EHV - Electro Hydraulic Servo Valve

ETS - Engineering Technical Specialists

FCC - Flight Control Computer

IMA - Intermediate Maintenance Activity

MALS - Marine Aviation Logistics Squadron

MDA - McDonnell Douglas Aircraft

MTBF - Mean Time Between Failure

NADEP - Naval Aviation Depot

NALDA - Naval Aviation Logistics Data

NAMP - Naval Aviation Maintenance Program

NAVICP - Navy Inventory Control Point

NETS - Navy Engineering Technical Specialists

NPV - Net Present Value

OEM - Original Equipment Manufacturer

PIMA - Prime Intermediate Maintenance Activity

STS - Servocylinder Test Station

TEF/HS - Trailing Edge Flap, Hydraulic Servovalve

TWP - Test Workaround Procedure

WSPD - Weapons System Planning Document

(In Thousands ($))

| Years | NPV | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ***Super "I" Savings*** | | | | | | | | | | | | |
| **Bench Relocation** | | ($20) | | | | | | | | | | |
| **AVDLR ($) Saved** | | | $3,881 | $3,881 | $3,881 | $3,881 | $3,881 | $3,881 | $3,881 | $3,881 | $3,881 | $3,881 |
| **Transportation** | | | ($182) | ($182) | ($182) | ($182) | ($182) | ($182) | ($182) | ($182) | ($182) | ($182) |
| **Manpower** | | | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 | $0 |
| **Total** | $36,970 | ($20) | $3,699 | $3,699 | $3,699 | $3,699 | $3,699 | $3,699 | $3,699 | $3,699 | $3,699 | $3,699 |
| **Discount Rate 10%** | | 1.0000 | 0.9091 | 0.8264 | 0.7513 | 0.683 | 0.6209 | 0.5645 | 0.5132 | 0.4665 | 0.4241 | 0.3855 |
| **Discounted Total** | **$22,709** | ($20) | $3,363 | $3,057 | $2,779 | $2,526 | $2,297 | $2,088 | $1,898 | $1,726 | $1,569 | $1,426 |
| | | | | | | | | | | | | |
| ***Design Improvements*** | | | | | | | | | | | | |
| **Addit. AVDLR ($) Saved** | | | $1,525 | $1,525 | $1,525 | $1,525 | $1,525 | $1,525 | $1,525 | $1,525 | $1,525 | $1,525 |
| **Addit. Spares Reduction*** | | | $1,713 | $1,713 | $1,713 | $1,713 | $1,713 | $1,713 | $1,713 | $1,713 | $1,713 | $1,713 |
| **Total** | $32,380 | $0 | $3,238 | $3,238 | $3,238 | $3,238 | $3,238 | $3,238 | $3,238 | $3,238 | $3,238 | $3,238 |
| **Discount Rate 10%** | | 1.0000 | 0.9091 | 0.8264 | 0.7513 | 0.683 | 0.6209 | 0.5645 | 0.5132 | 0.4665 | 0.4241 | 0.3855 |
| **Discounted Total** | **$19,896** | $0 | $2,944 | $2,676 | $2,433 | $2,212 | $2,010 | $1,828 | $1,662 | $1,511 | $1,373 | $1,248 |
| | | | | | | | | | | | | |
| ***Combined Totals*** | | | | | | | | | | | | |
| **Total** | $69,350 | | | | | | | | | | | |
| **Discounted Total** | **$42,604** | | | | | | | | | | | |

Super "I" Savings - Based on values outlined in Figures 10, 11 & 12

Design Improvements - Based on MTBF increase to 409 hours. Values outlined in Figures 13, 14 & 15.

**Additional Spares Reduction - Reducing the Super "I" Spares Pool by 17 units maintains an Aircraft TEF, HS Readiness of 97%.

**APPENDIX B**

| *Navy Inputs* | |
|---|---|
| # Navy A/C NASL | 158 |
| MTBF | 201 |
| BCM % | 39% |
| "D" TAT (hrs) | 1056 |
| "I" TAT (hrs) | 756 |
| Shipping time "D" to "I" | 144 |
| # Navy Spares | 19 |
| *Outputs* | |
| TEF, HS Oper Avail (Navy) | 78% |
| Total BCM to Depot | 258 |
| AVDLR Charges | $3,952,877 |
| Spare Parts Pool Balance | 0 |
| Aircraft TEF, HS Readiness | 84% |

| *Marine Corps Inputs* | |
|---|---|
| # Marine Corps A/C MALS-11 | 117 |
| MTBF | 201 |
| BCM % | 39% |
| "D" TAT (hrs) | 1056 |
| "I" TAT (hrs) | 756 |
| Shipping time "D" to "I" | 144 |
| # Marine Corps Spares | 14 |
| *Outputs* | |
| TEF, HS Oper Availability (MC) | 78% |
| Total BCM to Depot | 191 |
| AVDLR Charges | $2,927,130 |
| Spare Parts Pool Balance | 0 |
| Aircraft TEF, HS Readiness | 84% |

| *Super Hyd "I" Inputs* | |
|---|---|
| # A/C MALS-11 & NASL | 275 |
| MTBF | 409 |
| BCM % | 17% |
| "D" TAT (hrs) | 576 |
| "I" TAT (hrs) | 480 |
| Shipping time "D" to "I" | 144 |
| Shipping time Super to NASL | 24 |
| # MALS 11 & NASL Spares | 16 |
| *Outputs* | |
| TEF, HS Oper Availability (Spr) | 94% |
| Total BCM to Depot | 96 |
| AVDLR Charges | $1,473,825 |
| Spare Parts Pool Balance | 0 |
| Aircraft TEF, HS Readiness | 97% |

| | |
|---|---|
| A:F26: | ((((C20*2))*(24*365))-(((((C20*2)*35)*12/C21)*C22*C23)+((((C20*2)*35)*12/C21)*C22*C25)+((((C20*2)*35)*12/C21)*(1-C22)*C24)))/(((C20*2)*(24*365))) |
| A:G26: | TEF, Read |
| A:B28: | Outputs |
| A:B29: | TEF, HS Oper Availability (MC) |
| A:C29: | @IF(F26>1,1,F26) |
| A:B30: | Total BCM to Depot |
| A:C30: | ((C20*2*35*12)/C21)*C22 |
| A:B31: | AVDLR Charges |
| A:C31: | +C30*15350 |
| A:B32: | Spare Parts Pool Balance |
| A:C32: | @IF(F22>0,F22,0) |
| A:B33: | Aircraft TEF, HS Readiness |
| A:C33: | @IF(F24>1,1,F24) |
| A:B36: | Super Hyd "I" Inputs |
| A:B37: | "# A/C MALS-11 & NASL |
| A:C37: | 275 |
| A:B38: | MTBF |
| A:C38: | 409 |
| A:F38: | Spares Balance Calc |
| A:B39: | BCM % |
| A:C39: | 0.17 |
| A:F39: | (F48*(2*C37))-(2*C37)+C44 |
| A:B40: | ""D" TAT (hrs) |
| A:C40: | +24*24 |
| A:B41: | ""I" TAT (hrs) |
| A:C41: | +20*24 |
| A:B42: | Shipping time "D" to "I" |
| A:C42: | +6*24 |
| A:B43: | Shipping time Super to NASL |
| A:C43: | 24 |
| A:F43: | AC read |
| A:B44: | "# MALS 11 & NASL Spares |
| A:C44: | 16 |
| A:F44: | (C37*2+F39)/(2*C37) |
| A:F45: | spares |
| A:B46: | Outputs |
| A:B47: | TEF, HS Oper Availability (Spr) |
| A:C47: | @IF(F48>1,1,F48) |
| A:F47: | TEF, Read |
| A:B48: | Total BCM to Depot |
| A:C48: | ((2*C37*35*12)/C38)*C39 |
| A:F48: | ((((C37*2))*(24*365))-(((((C37*2)*35)*12/C38)*C39*C40)+((((C37*2)*35)*12/C38)*C39*C42)+((((C3*2)*35)*12/C4)*(1-C5)*C43)+((((C37*2)*35)*12/C38)*(1-C39)*C41)))/(((C37*2)*(24*365))) |
| A:B49: | AVDLR Charges |
| A:C49: | +C48*15350 |
| A:B50: | Spare Parts Pool Balance |
| A:C50: | @IF(F39>0,F39,0) |
| A:B51: | Aircraft TEF, HS Readiness |
| A:C51: | @IF(F44>1,1,F44) |

A:B2: Navy Inputs
A:F2: Input ONLY
A:B3: "# Navy A/C NASL
A:C3: 158
A:F3: colored cells.
A:B4: MTBF
A:C4: 201
A:F4: Spares Balance Calc
A:B5: BCM %
A:C5: 0.39
A:F5: (F9*(2*C3))-(C3*2)+C9
A:B6: ""D" TAT (hrs)
A:C6: +44*24
A:B7: ""I" TAT (hrs)
A:C7: +31.5*24
A:F7: (C3*2+F5)/(2*C3)
A:G7: AC read
A:B8: Shipping time "D" to "I"
A:C8: +6*24
A:G8: spares
A:B9: "# Navy Spares
A:C9: 19
A:F9: ((((C3*2))*(24*365))-(((((C3*2)*35)*12/C4)*C5*C6)+((((C3*2)*35)*12/C4)*C5*C8)+((((C3*2)*35)*12/C4)*(1-C5)*C7)))/(((C3*2)*(24*365)))
A:G9: TEF, Read
A:B11: Outputs
A:B12: TEF, HS Oper Avail (Navy)
A:C12: @IF(F9>1,1,F9)
A:B13: Total BCM to Depot
A:C13: ((C3*2*35*12)/C4)*C5
A:B14: AVDLR Charges
A:C14: +C13*15350
A:B15: Spare Parts Pool Balance
A:C15: @IF(F5>0,F5,(0))
A:B16: Aircraft TEF, HS Readiness
A:C16: @IF(F7>1,1,F7)
A:B19: Marine Corps Inputs
A:B20: "# Marine Corps A/C MALS-11
A:C20: 117
A:B21: MTBF
A:C21: 201
A:F21: Spares Balance Calc
A:B22: BCM %
A:C22: 0.39
A:F22: (F26*(2*C20))-(C20*2)+C26
A:B23: ""D" TAT (hrs)
A:C23: +44*24
A:B24: ""I" TAT (hrs)
A:C24: +31.5*24
A:F24: (C20*2+F22)/(2*C20)
A:G24: AC read
A:B25: Shipping time "D" to "I"
A:C25: +6*24
A:G25: spares
A:B26: "# Marine Corps Spares
A:C26: 14

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